

Application of Nuclear Science to Cultural Heritage

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Karlsruher Nuklidkarte
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Karlsruhe, 9 December 2008

Cultural heritage is the legacy of physical artifacts and intangible (immaterial) attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations.

Often though, what is considered cultural heritage by one generation may be rejected by the next generation, only to be revived by a succeeding generation.

- *Wikipedia*

Methods of Nuclear Science

non-destructive is the key

Dating (last 50 000 years)

^{14}C Dating with AMS (0.1-1 mg C)
Thermo (Opto) Luminescence
Electron Spin Resonance
Amino Acid Racimization

Material Analysis

Neutron Activation Analysis
Proton Induced X-ray Emission
Proton Induced γ -ray Emission
Rutherford Back Scattering
Synchrotron X-ray Fluorescence

Migration & Paleodiet

Mass Spectrometry of Stable Isotopes
 $^{13}\text{C}/^{12}\text{C}$, $^{15}\text{N}/^{14}\text{N}$, $^{18}\text{O}/^{16}\text{O}$, $^{34}\text{S}/^{32}\text{S}$,
 $^{87}\text{Sr}/(^{87}\text{Rb})/^{86}\text{Sr}$, $^{206}\text{Pb}/(^{238}\text{U})/^{204}\text{Pb}$

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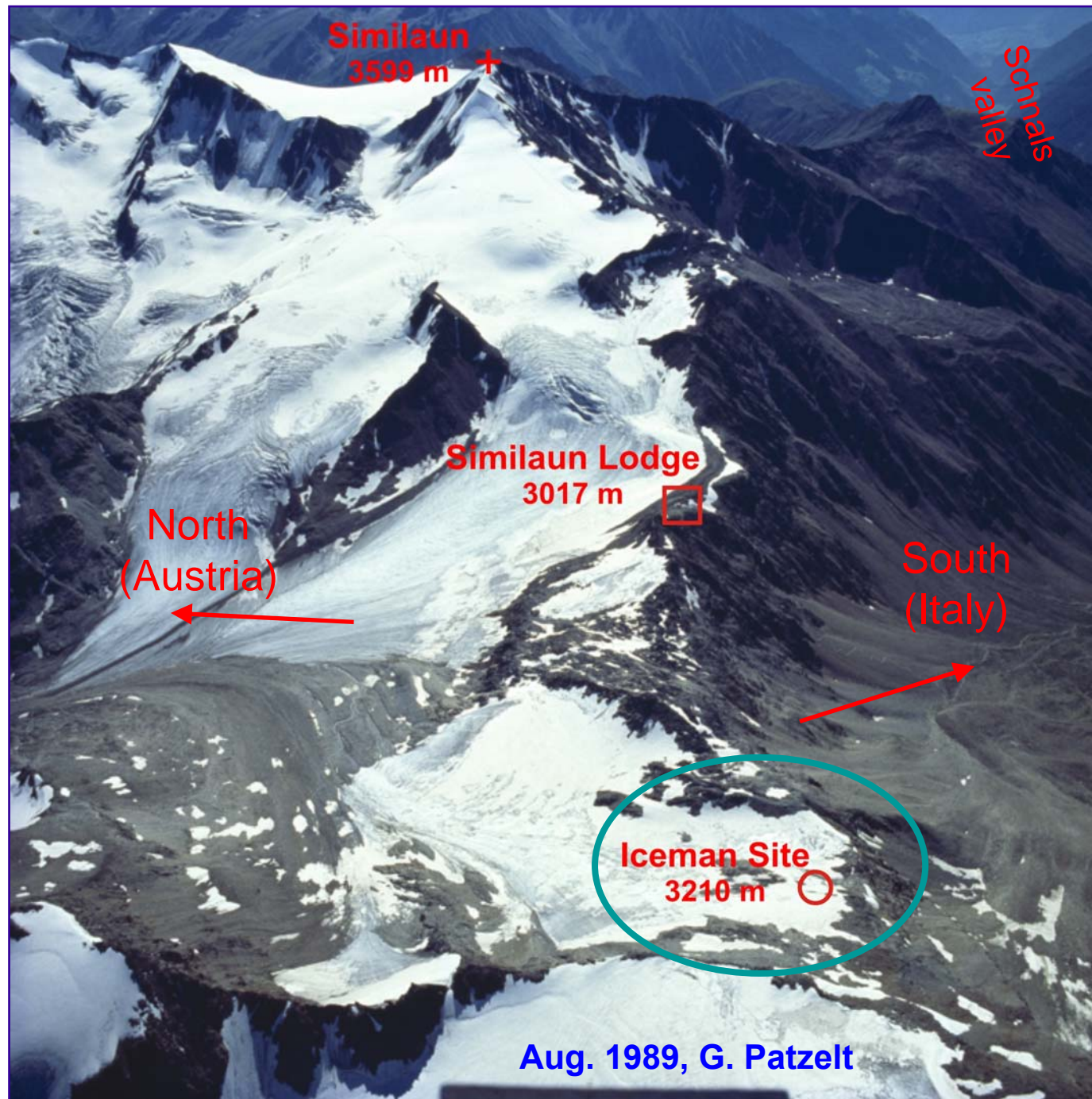
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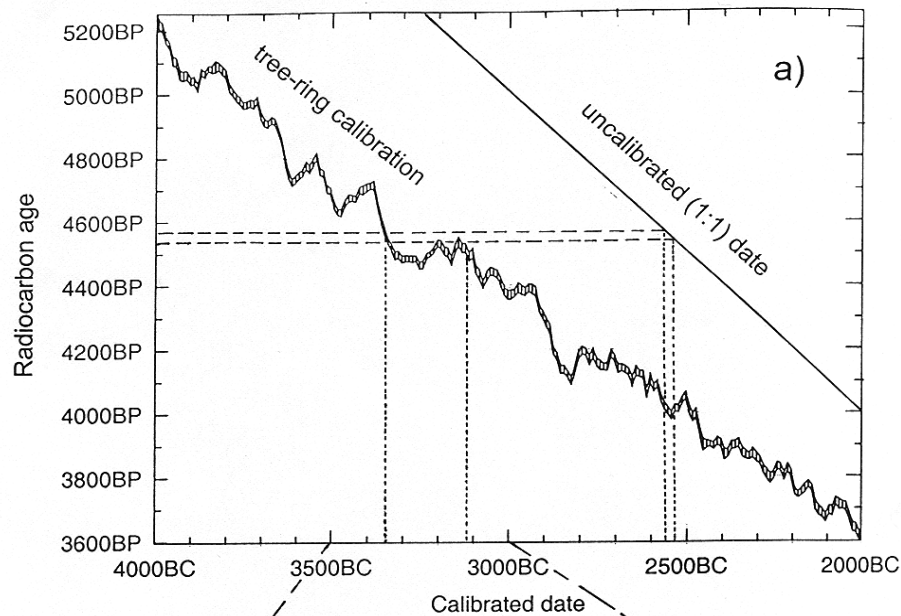
**^{14}C dating at the discovery site
of the Iceman Ötzi**

time range ~5000 years ago

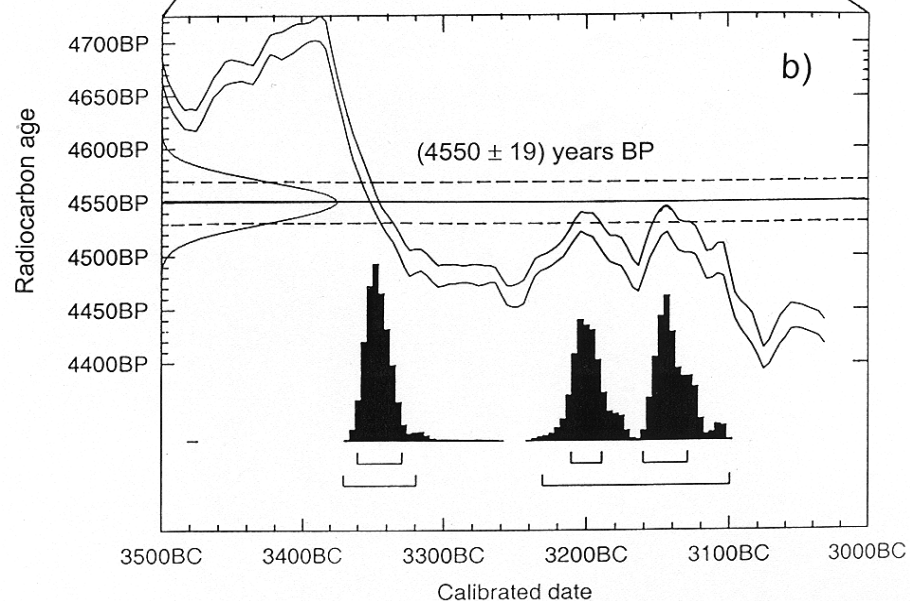




The Iceman Ötzi discovered in an Alpine Glacier, 1991



^{14}C dating of bone and tissue from the Iceman Ötzi at the AMS labs of Oxford and Zürich in 1992



**Uncalibrated (radiocarbon) age:
 $4550 \pm 19 \text{ yr BP}$ (before present)**

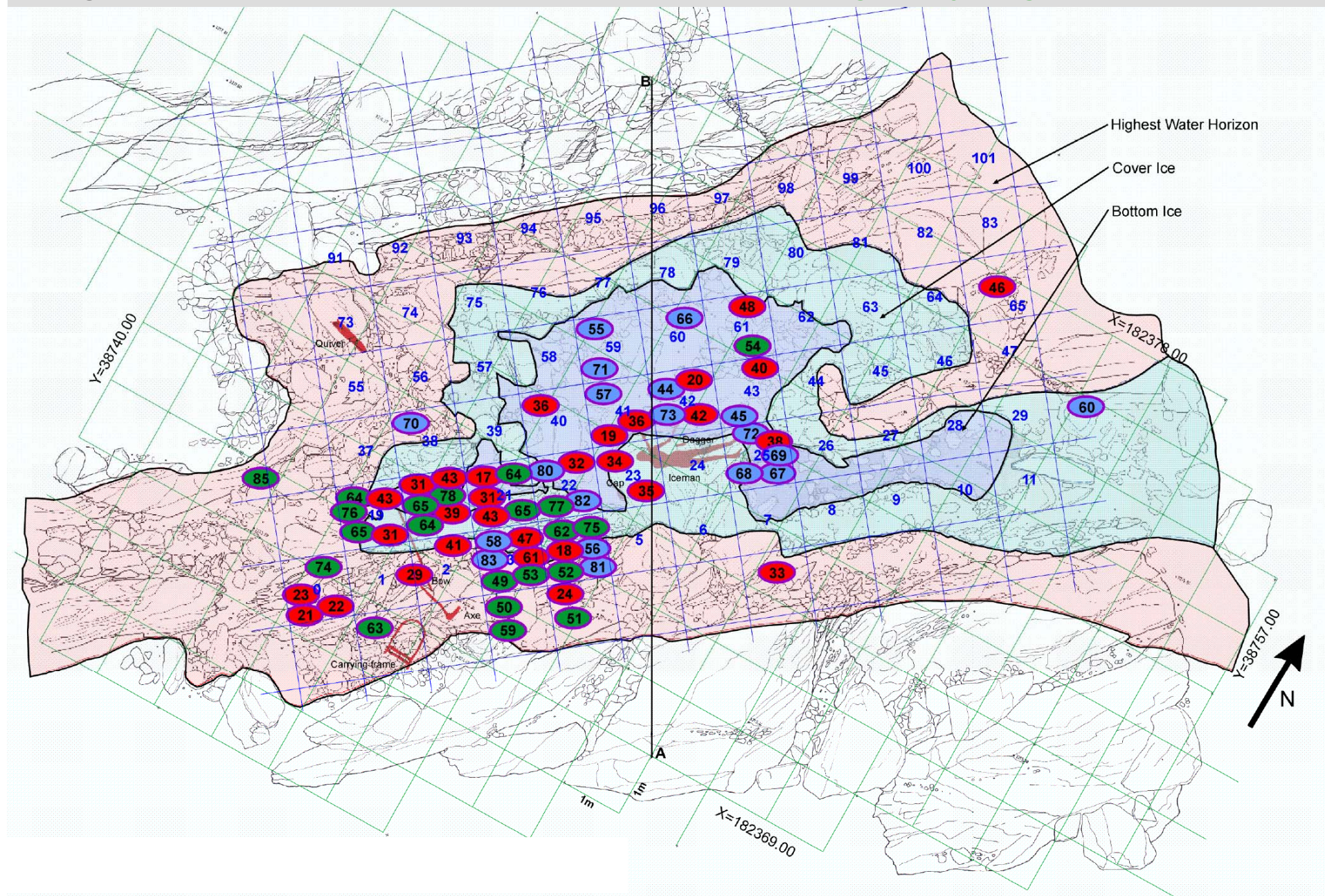
**Calibrated age range:
5300 to 5050 BP**

**View of the Iceman finding site at the end
of the excavation campaign in 1992
[A. Lippert et al.]**



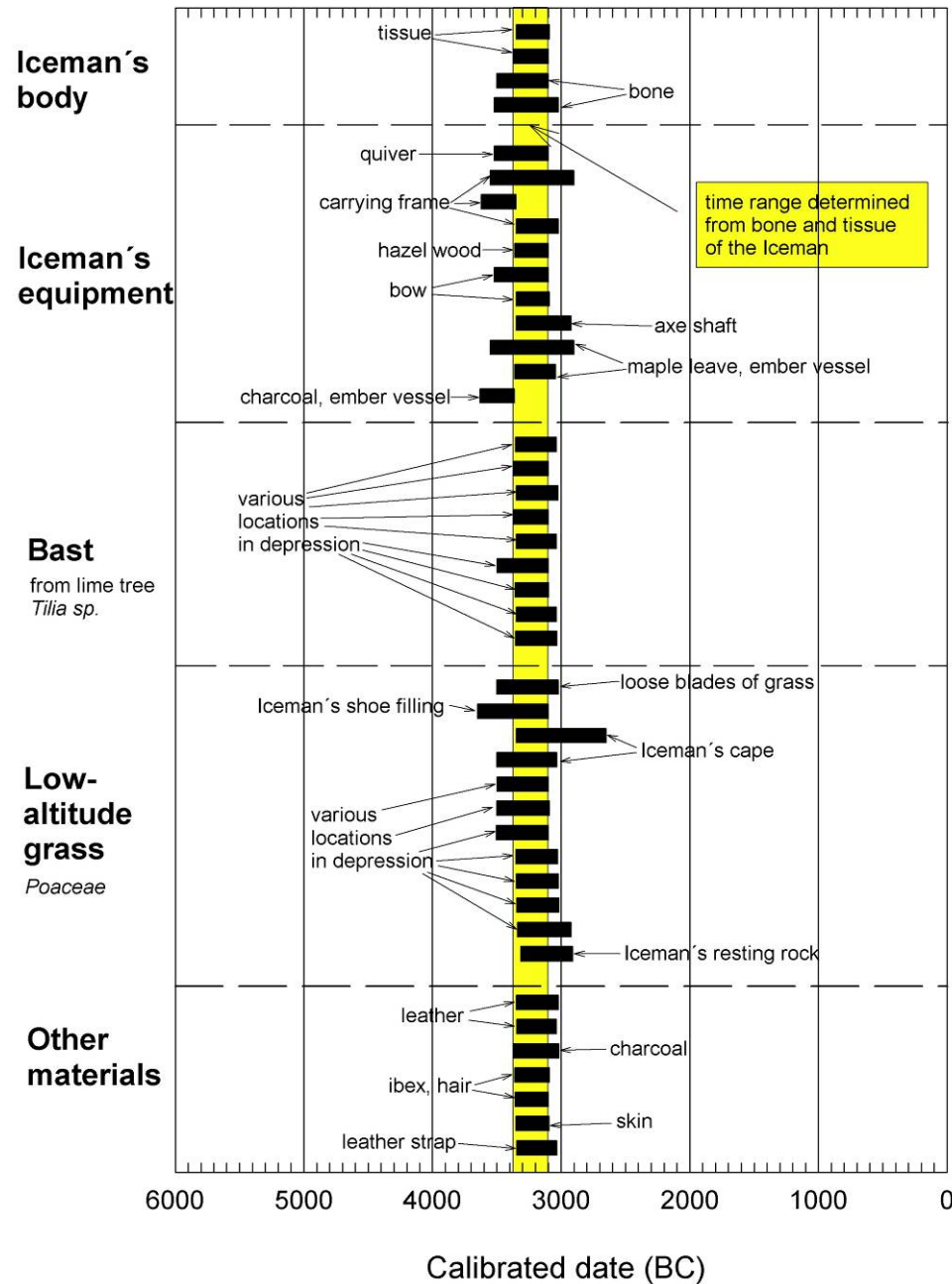
**Rock where the
Iceman was found**

Finding place of the Iceman and sample locations. The color code indicates different time ranges: **blue** (older than the Iceman), **red** (Iceman period), **green** (younger than the Iceman)



^{14}C dating of the Iceman and associated equipment

(all dates are calibrated 2-sigma ranges)

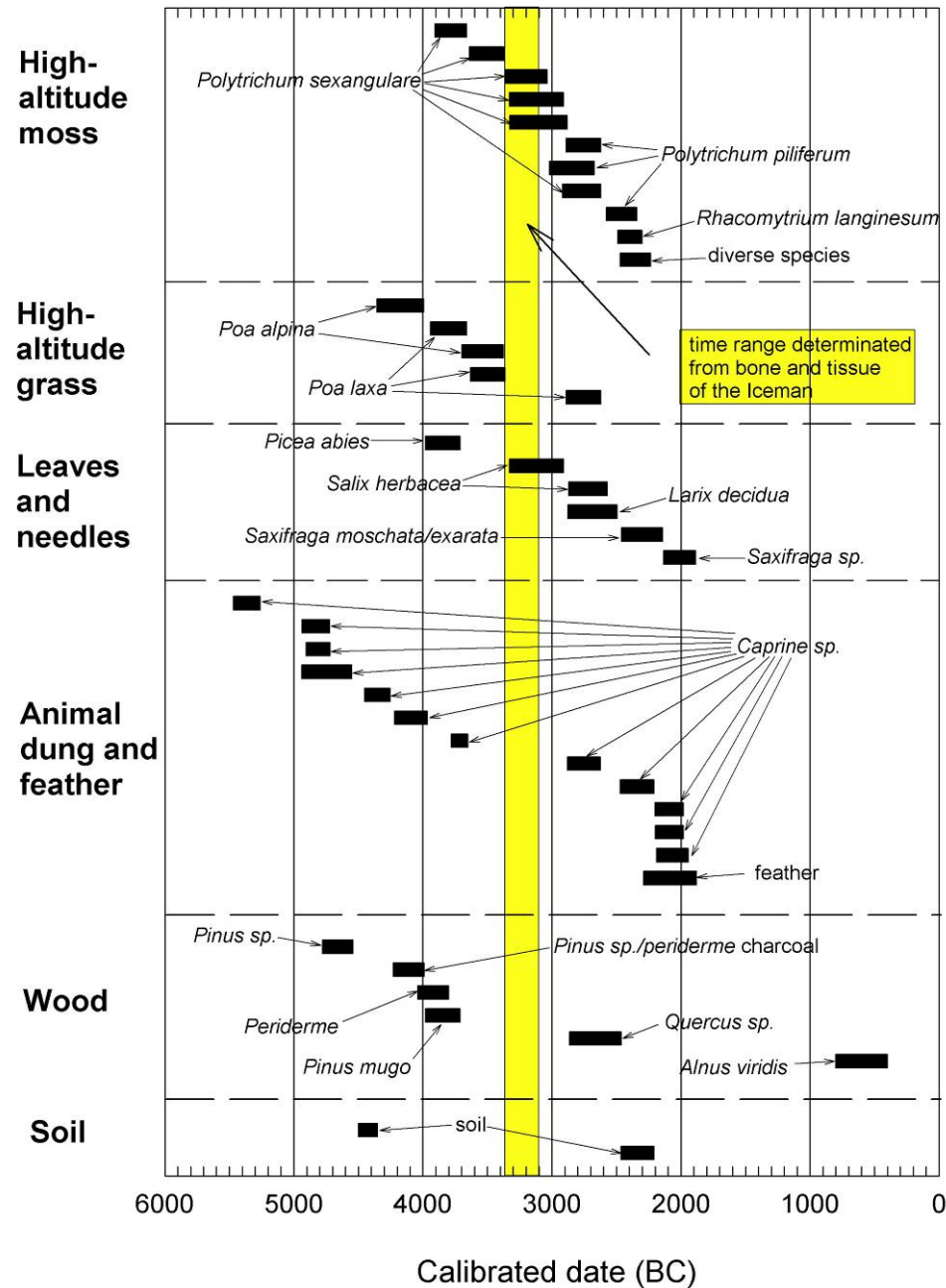


^{14}C dating at VERA of various materials found at the Discovery site of the Iceman Ötzi, **matching the date of the Iceman.**

W. K., W. Müller, Nucl. Instr. Meth. B 204 (2003) 705

^{14}C dating for various non-Iceman associated materials

(all dates are calibrated 2-sigma ranges)

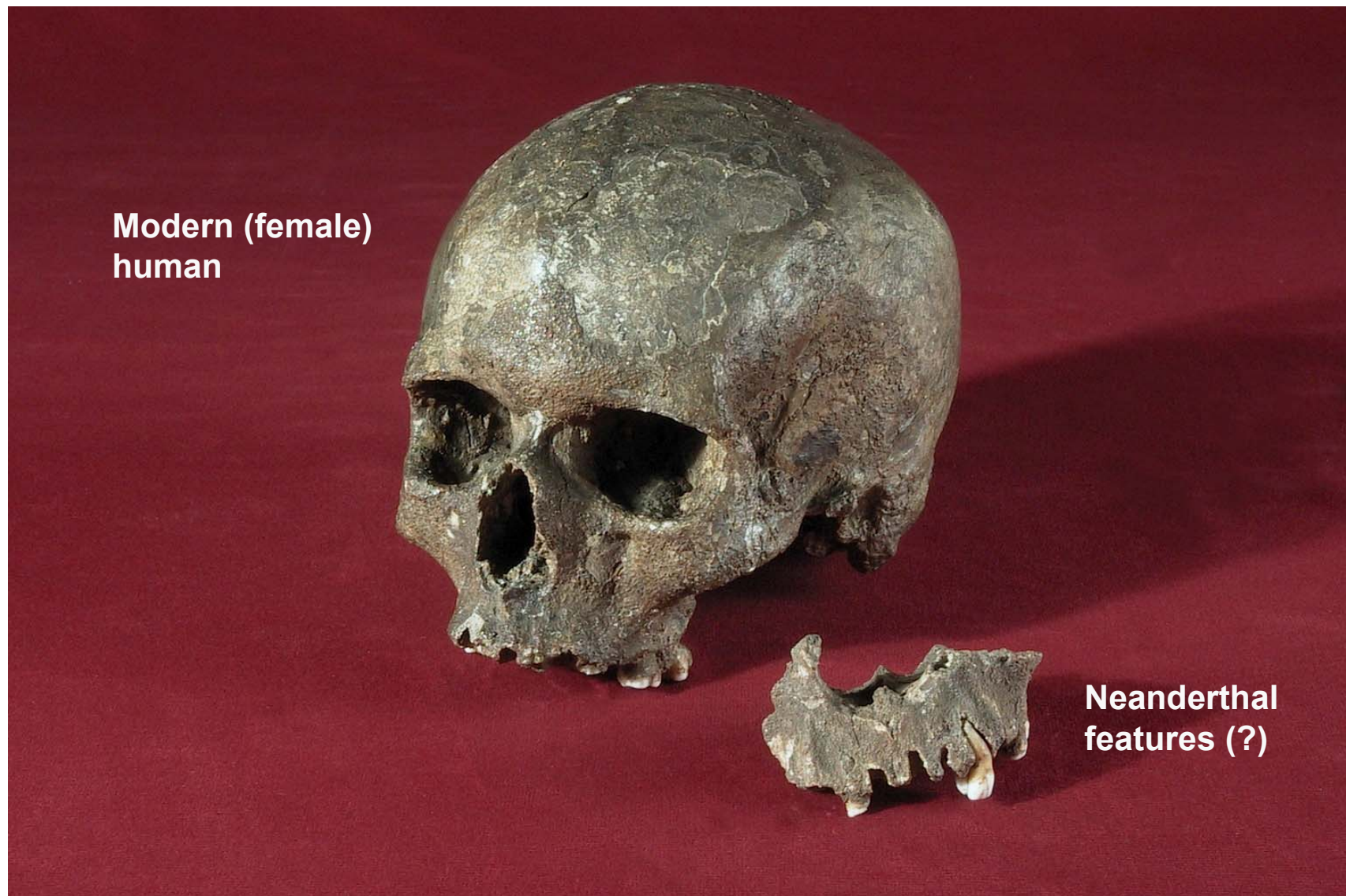


^{14}C dating at VERA of various materials found at the discovery site of the Iceman Ötzi, not matching the date of the Iceman.

W. K., W. Müller, Nucl. Instr. Meth. B 204 (2003) 705

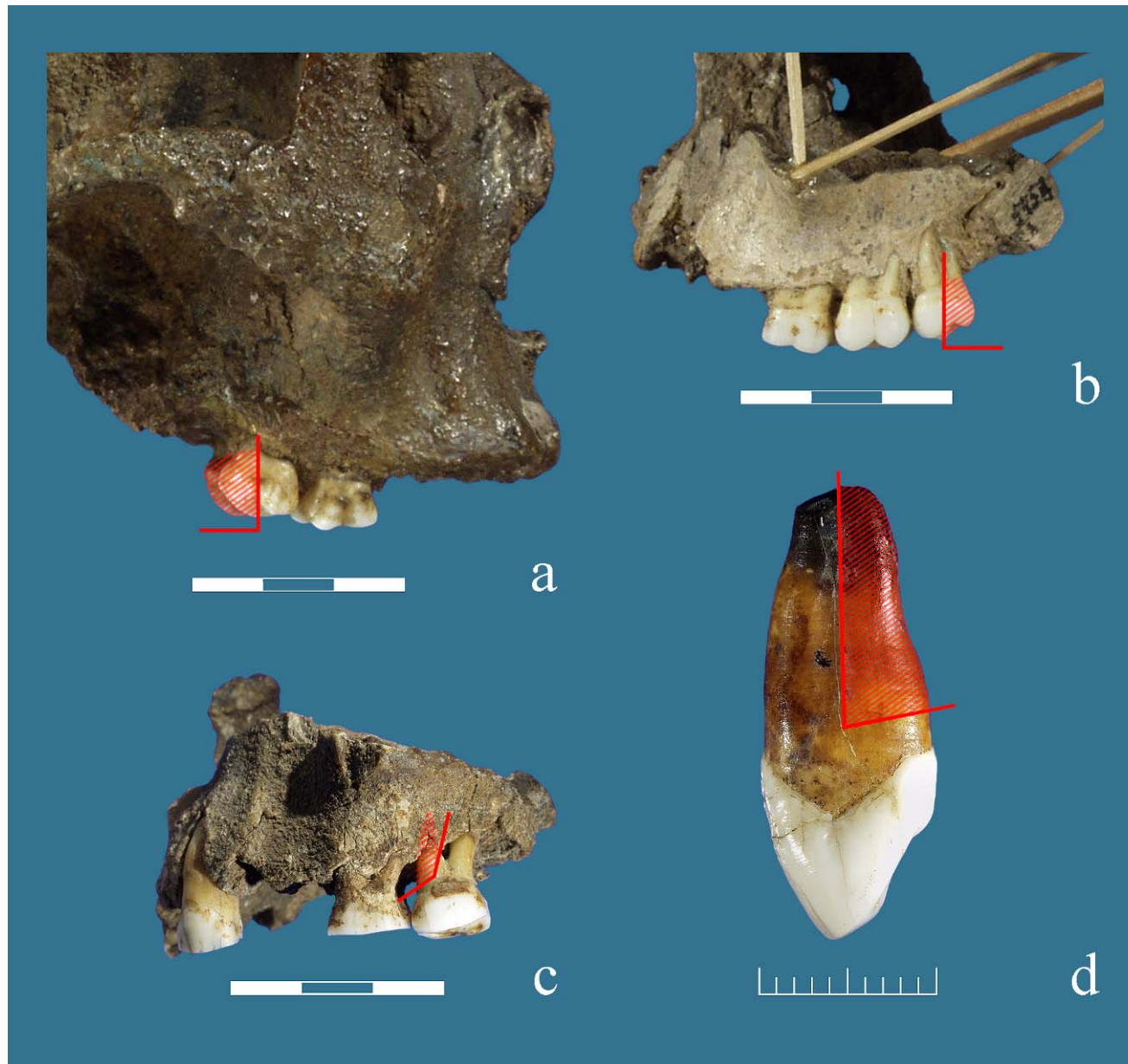
^{14}C dating of the first appearance of modern humans in Europe

time range 30 000 to 40 000 years ago



**Direct dating of Early Upper Paleolithic human remains from the
Mladeč Caves in Moravia (Czech Republic)**

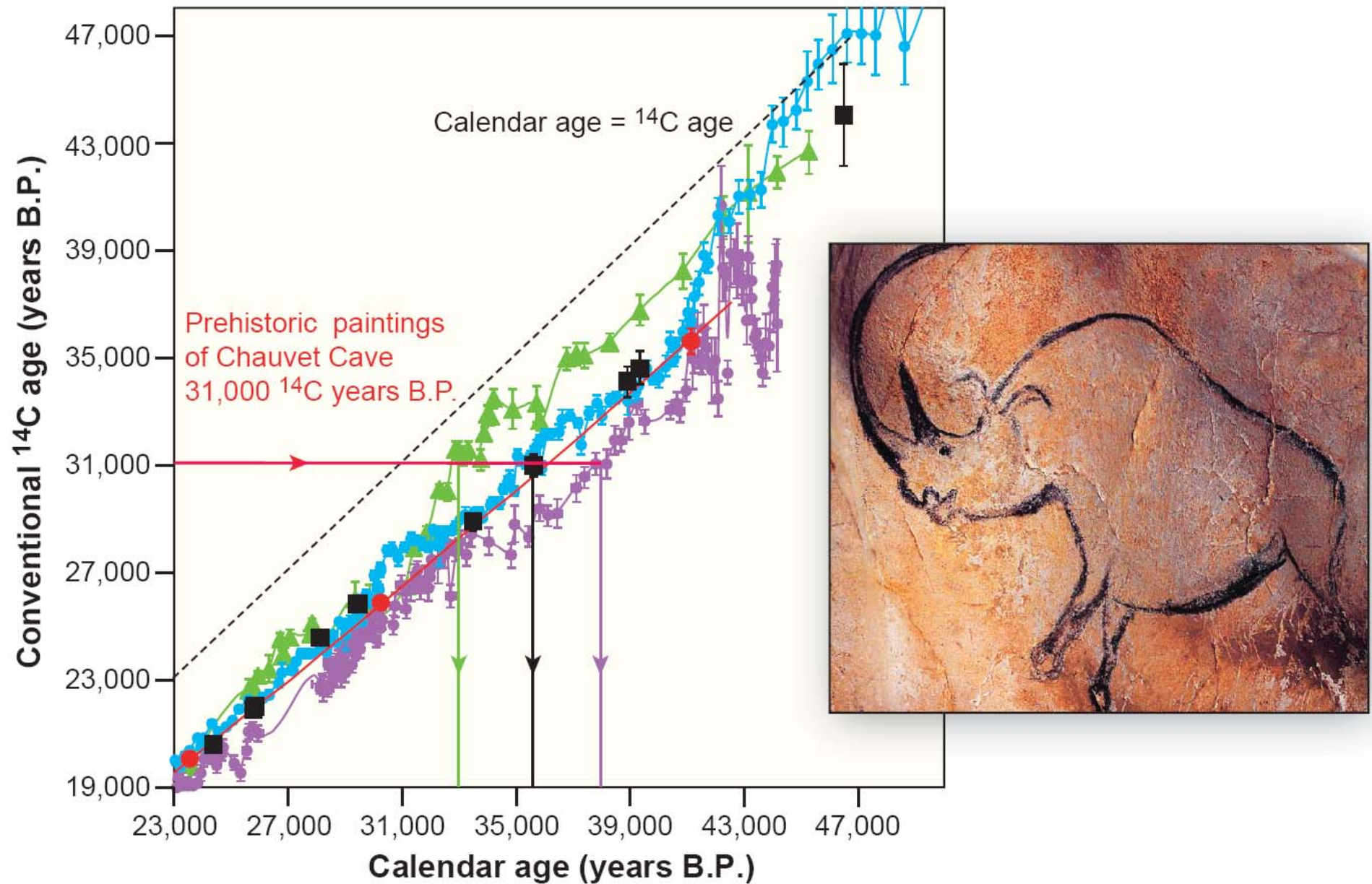
Eva Maria Wild et al., *Nature* 435 (2005) 322



Sampled areas for ^{14}C measurements at VERA

**Radiocarbon ages determined for the human remains from the
Mladeč site in Moravia (Czech Republic)**

Lab Number	Sample Name	Sample material	¹⁴C-age (years BP)
VERA-2736	Mladeč 25c	Ulna	26,330 ± 170
VERA-3073	Mladeč 1	Right molar M2 distal half of the crown	31,190 ± 400
VERA-3074	Mladeč 2	Left molar M3 distal half of the crown	31,320 ± 400
VERA-3075	Mladeč 8	Left molar M2 mesial-buccal root	30,680 ± 380
VERA-3076A	Mladeč 9a	Right maxillary canine, Lingual half of the root (white-coloured collagen)	31,500 ± 410
VERA-3076B	Mladeč 9a	Right maxillary canine, Lingual half of the root (brown-coloured collagen)	27,370 ± 230



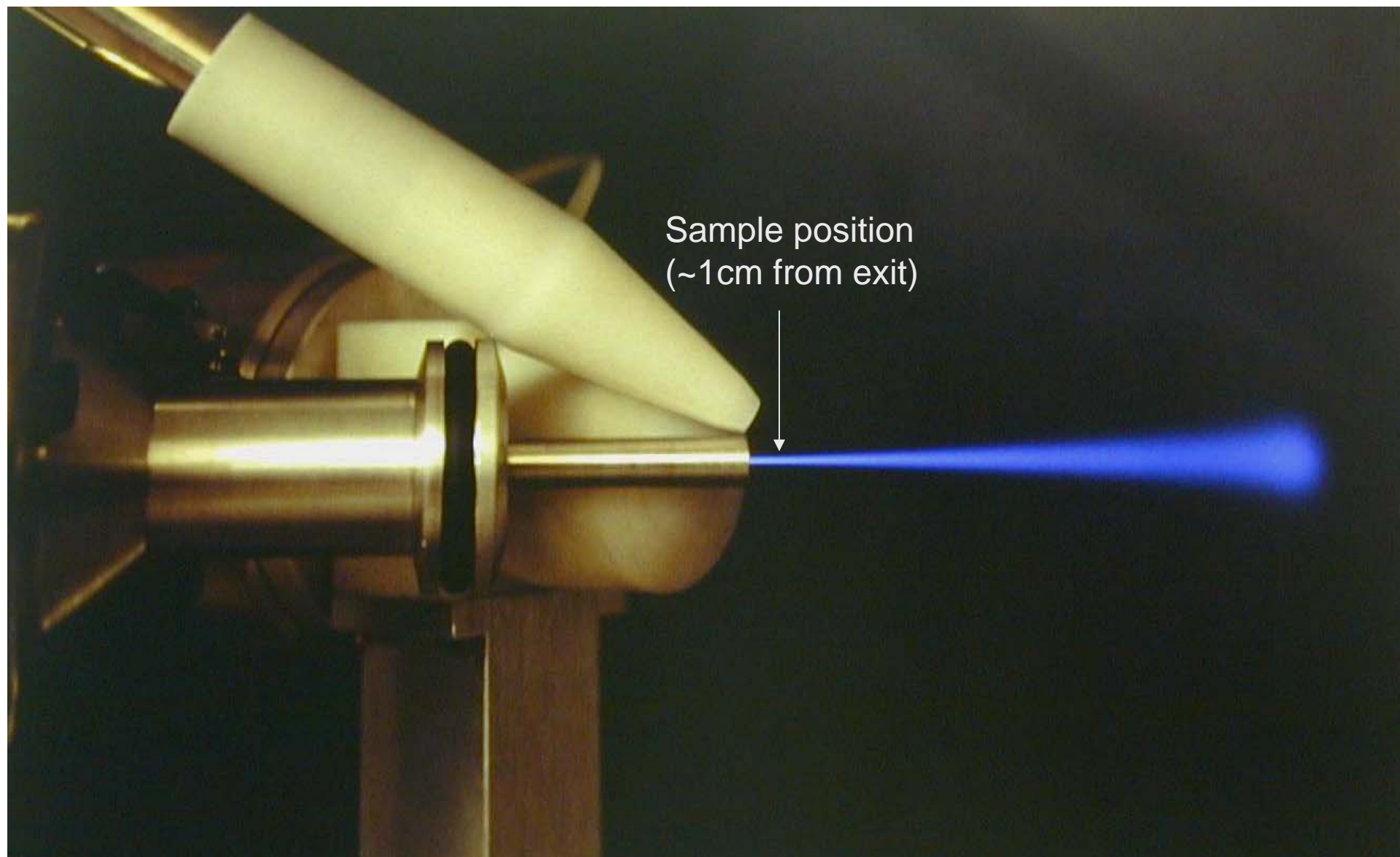
Radiocarbon calibration from 23,000 to 47,000 years BP (before present)

E. Bard et al., *A Better Radiocarbon Clock*, Science **303** (2004) 178

Analysing original silverpoint drawings of Albrecht Dürer with Proton-Induced X-ray Emission (PIXE)

time range ~500 years ago

Petra Milota et al., Nucl. Instr. Meth. B 266 (2008) 2279



**External 3-MeV Proton beam; range in air about 15 cm
(picture by Piero Mando, University of Florence)**



**Self portrait of Albrecht Dürer at
13, 1484**



**Portrait of the Artist's Father, Goldsmith
Albrecht Dürer the Elder, 1486**

From the collection of the Albertina Museum Vienna



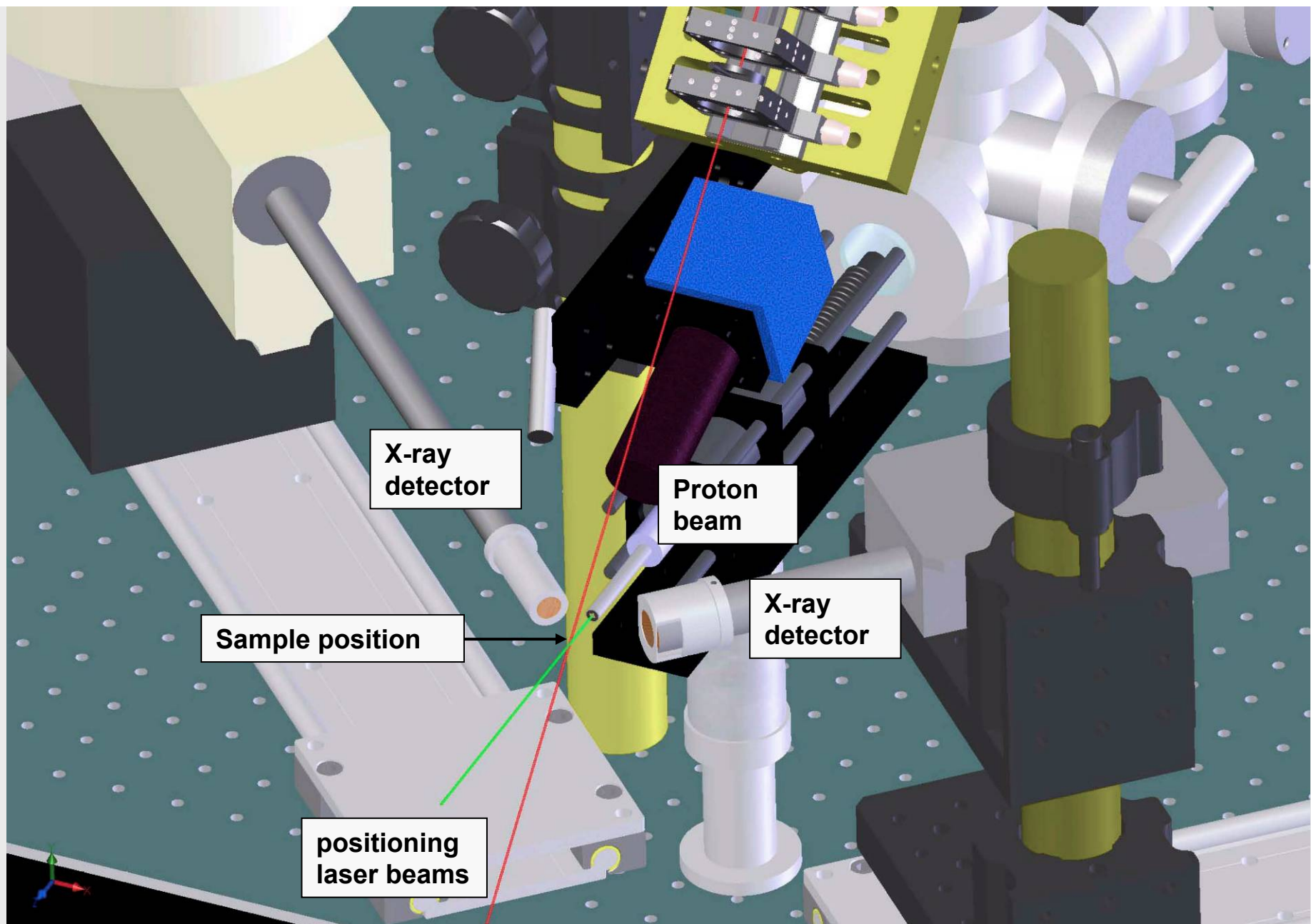
**Girl in Costume of Cologne;
Agnes Dürer (1521)**

Silverpoint on Paper, Albertina



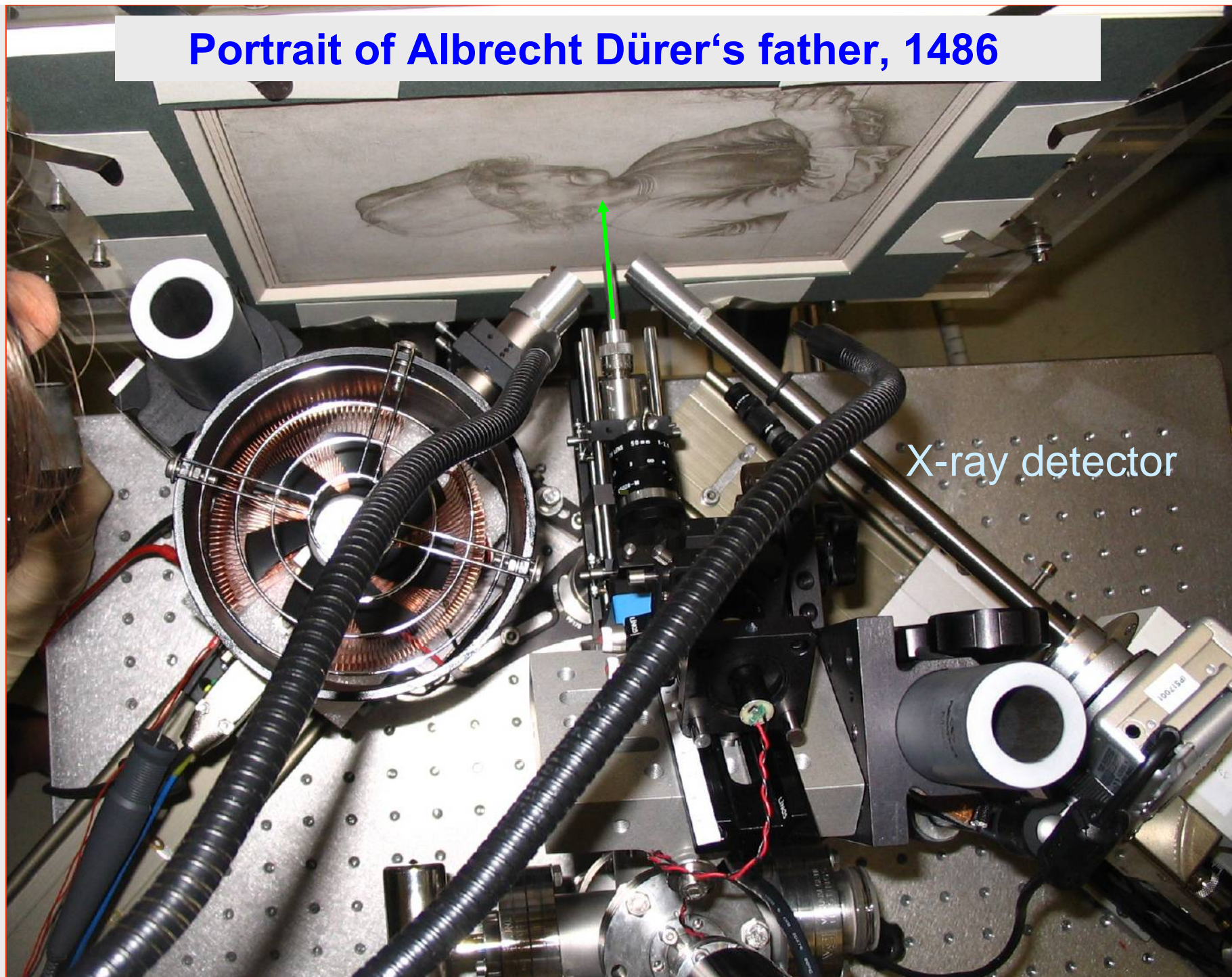
Lying Lion (1521)

Silverpoint on Paper, Albertina



PIXE setup at the Vienna Environmental Research Accelerator (VERA)

Portrait of Albrecht Dürer's father, 1486



X-ray detector

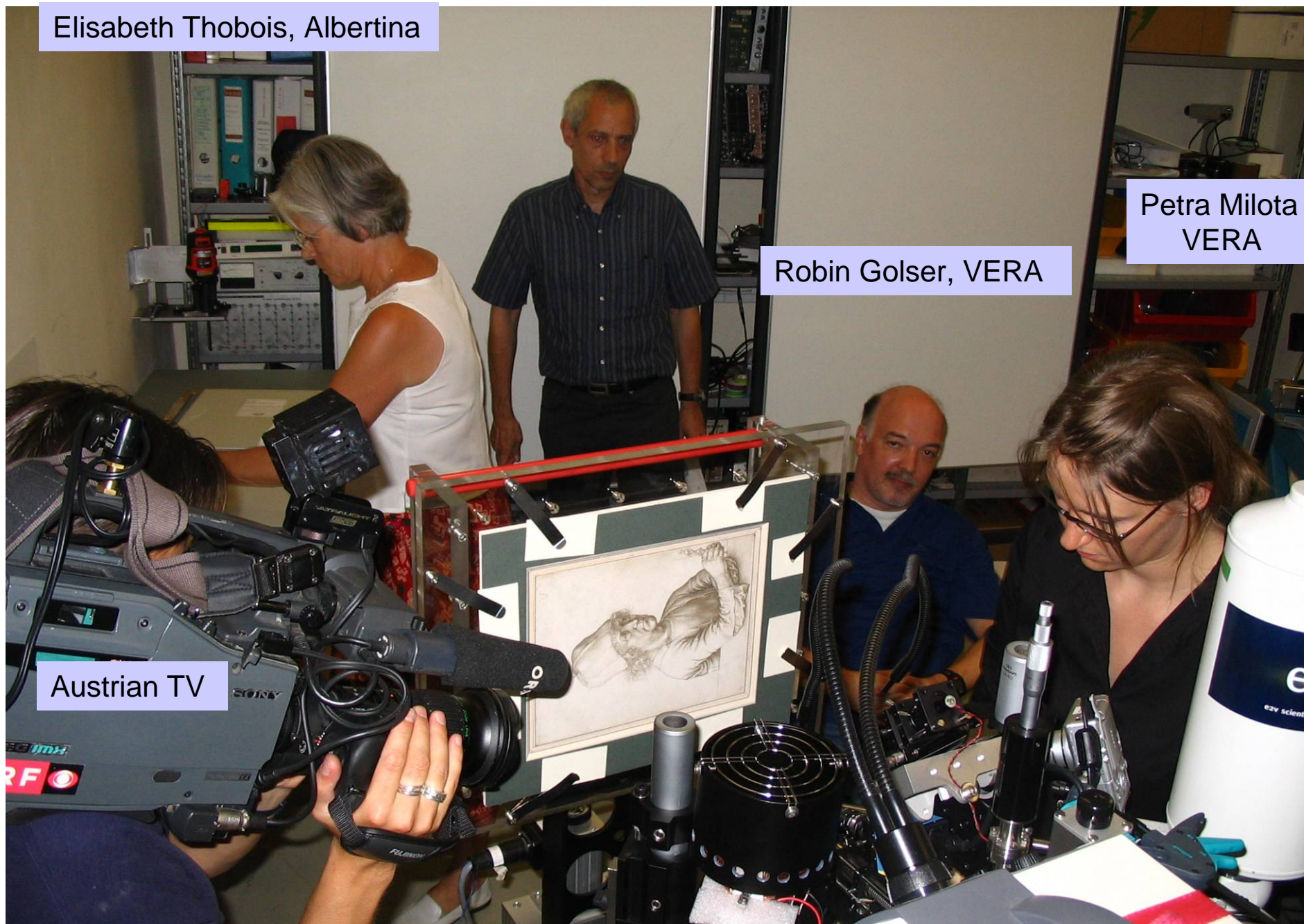
Alain Duval, Louvre

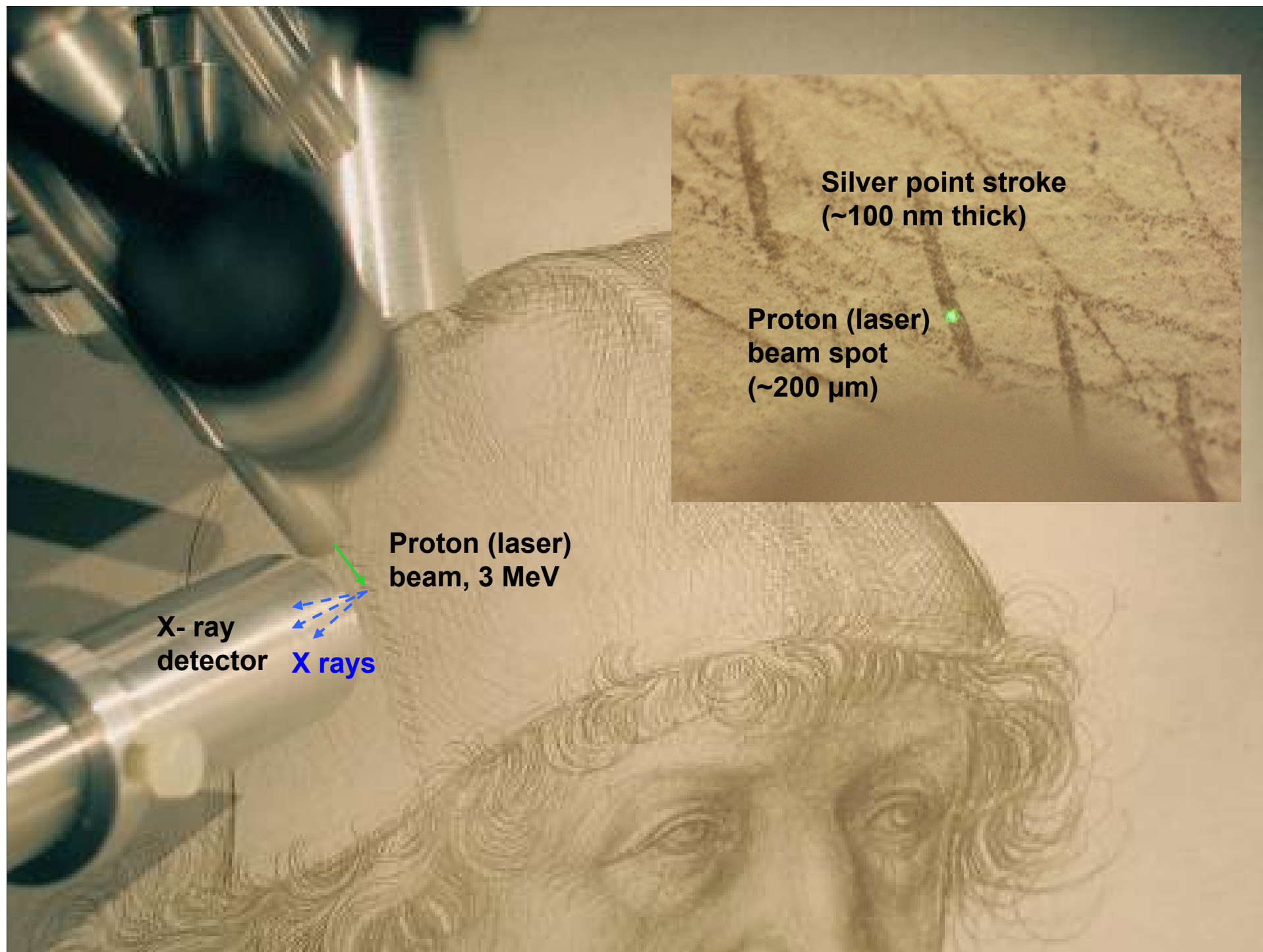
Elisabeth Thobois, Albertina

Petra Milota
VERA

Robin Golser, VERA

Austrian TV





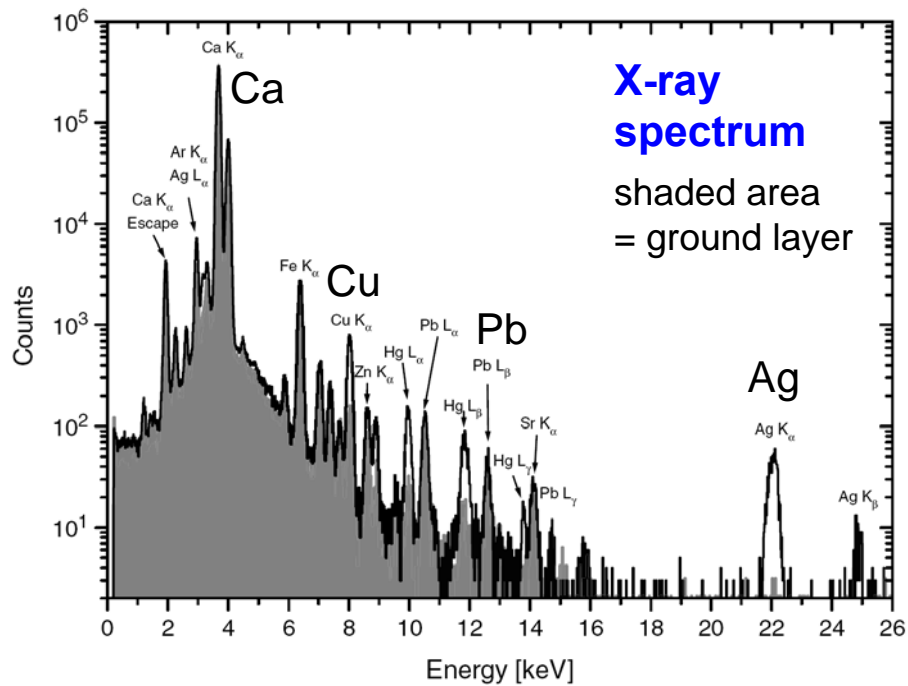
**Silver point stroke
(~100 nm thick)**

**Proton (laser)
beam spot
(~200 μm)**

**Proton (laser)
beam, 3 MeV**

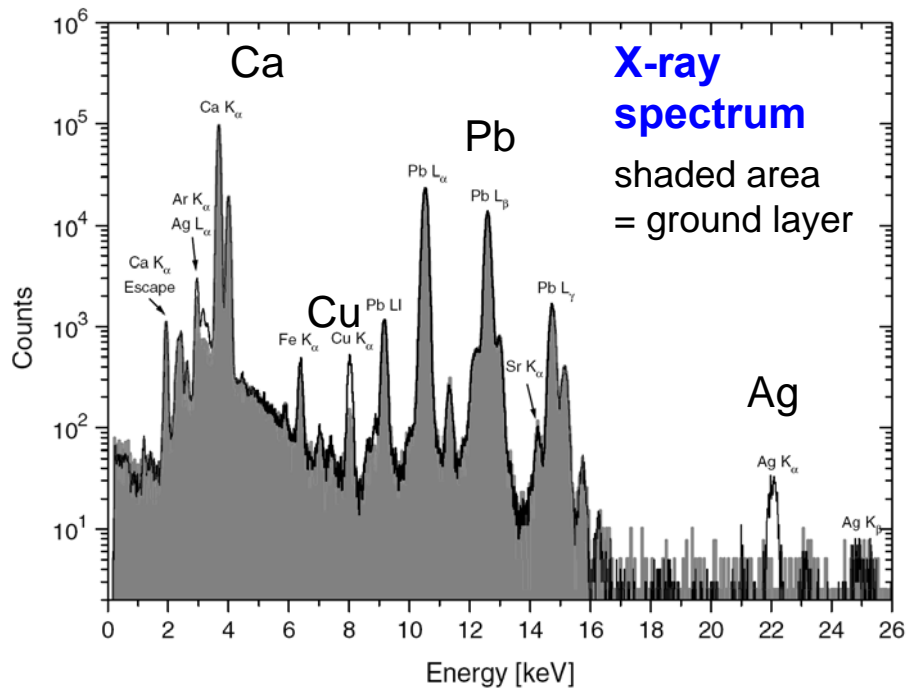
**X- ray
detector**

X rays

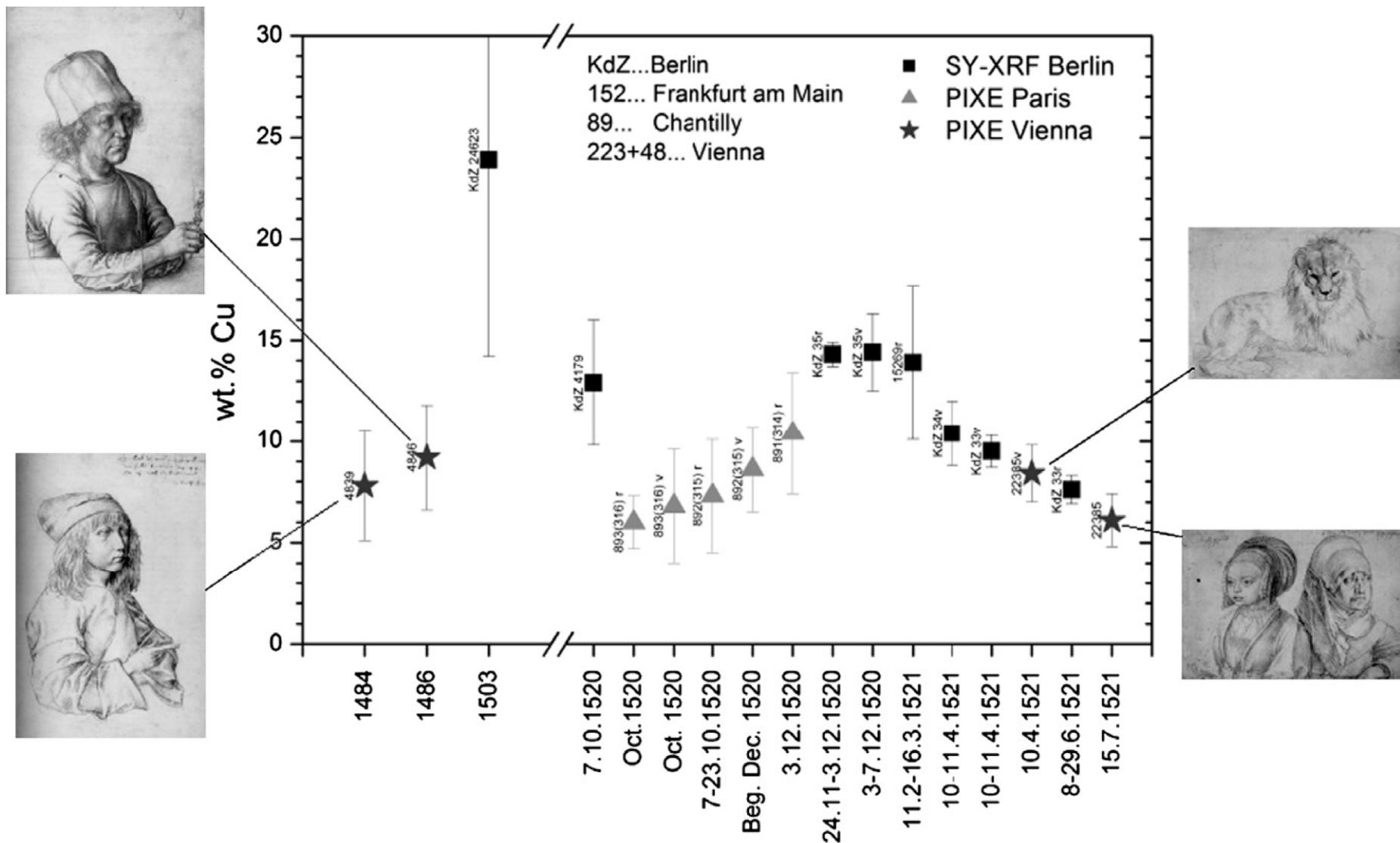


Girl in Costume of Cologne (1521)

Agnes Dürer



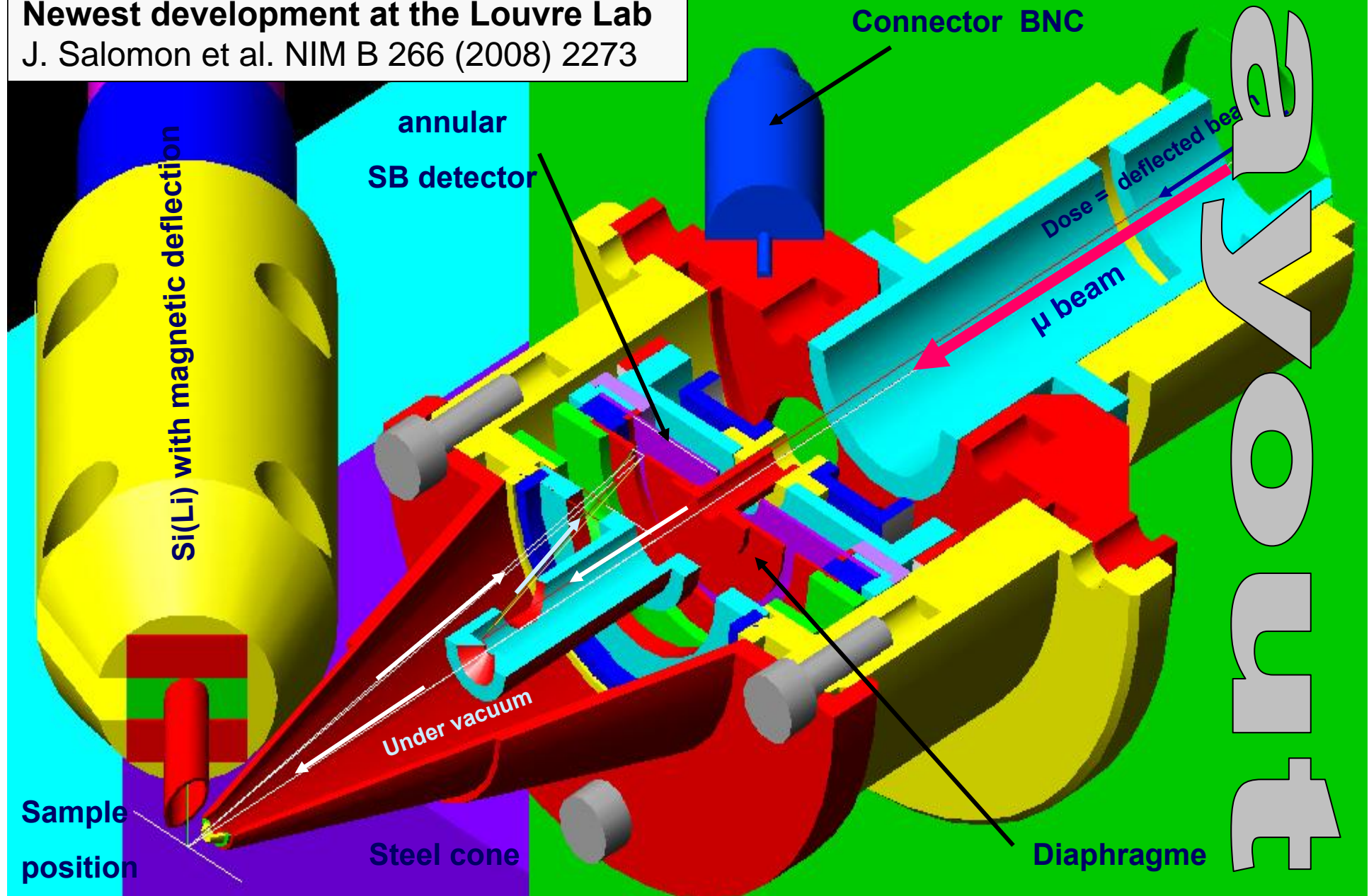
Portrait of the Artist's Father (1486)



Summary of Copper content of silverpoint drawings by Albrecht Dürer

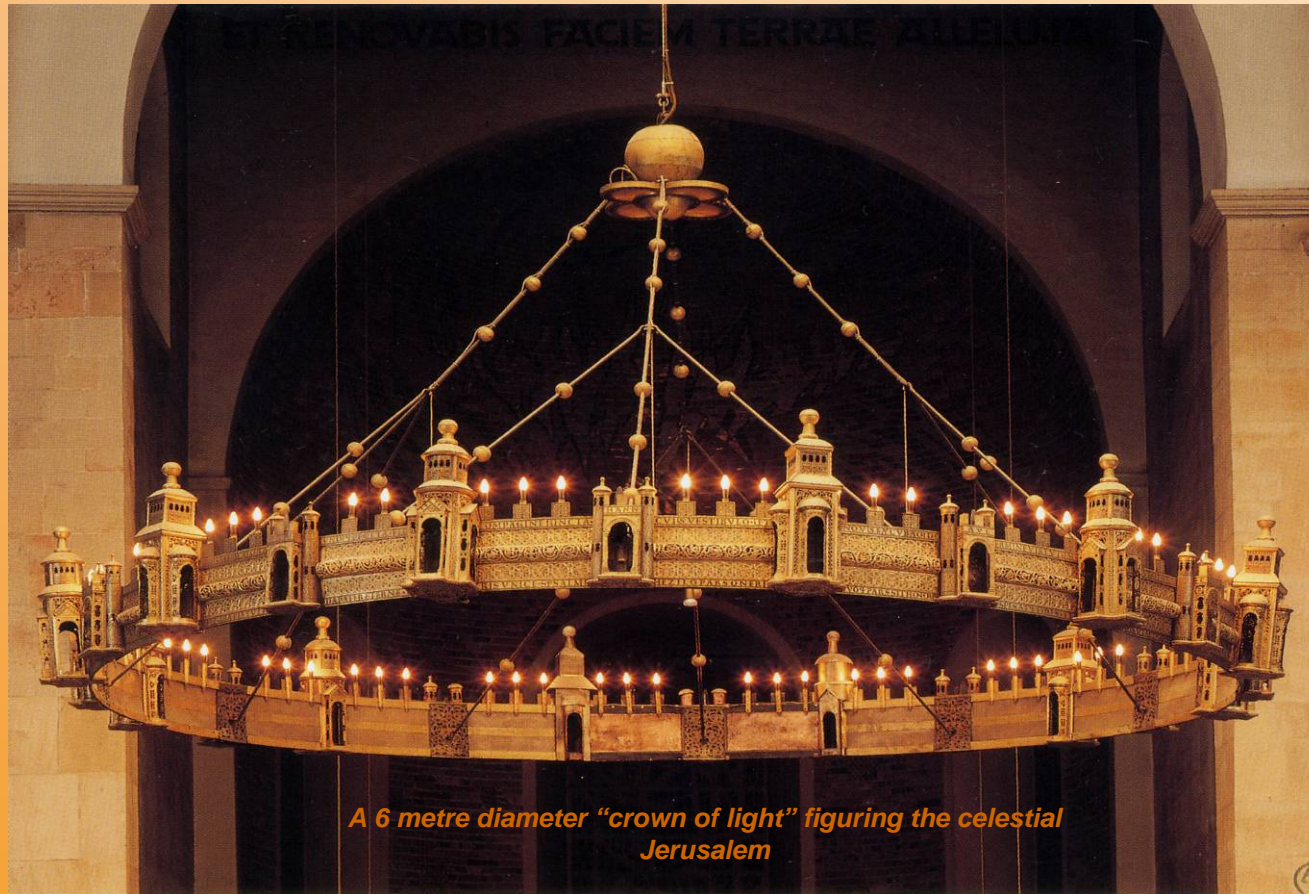
Nozzle with integrated SB Detector

Newest development at the Louvre Lab
J. Salomon et al. NIM B 266 (2008) 2273



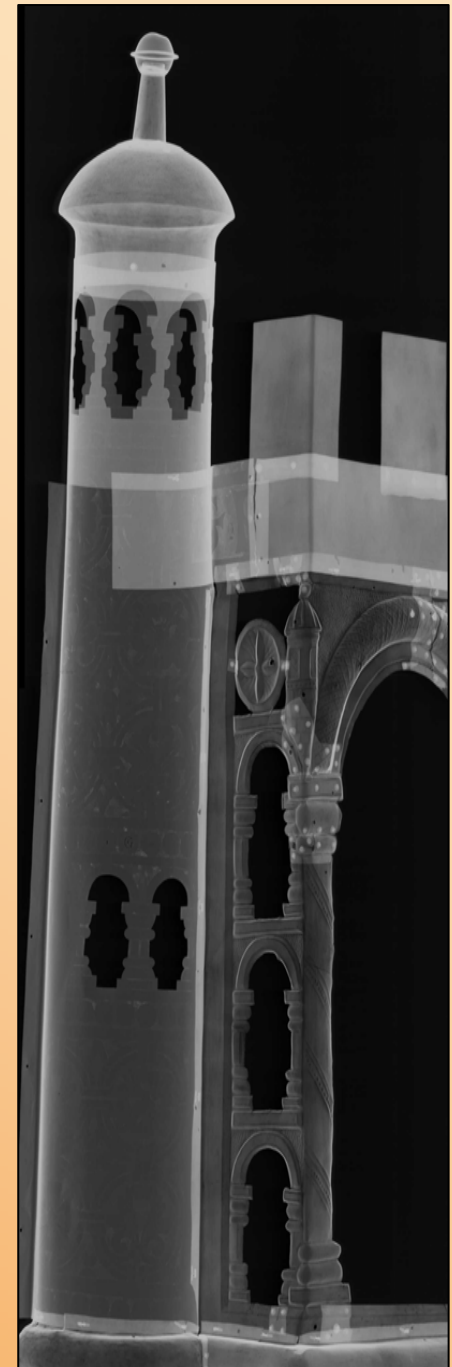
Investigations on part of the copper chandelier from the Hildesheim Dom Cathedral “The Hezilo Leuchter“

(B. Mille, Th. Borel, M. Aucouturier)

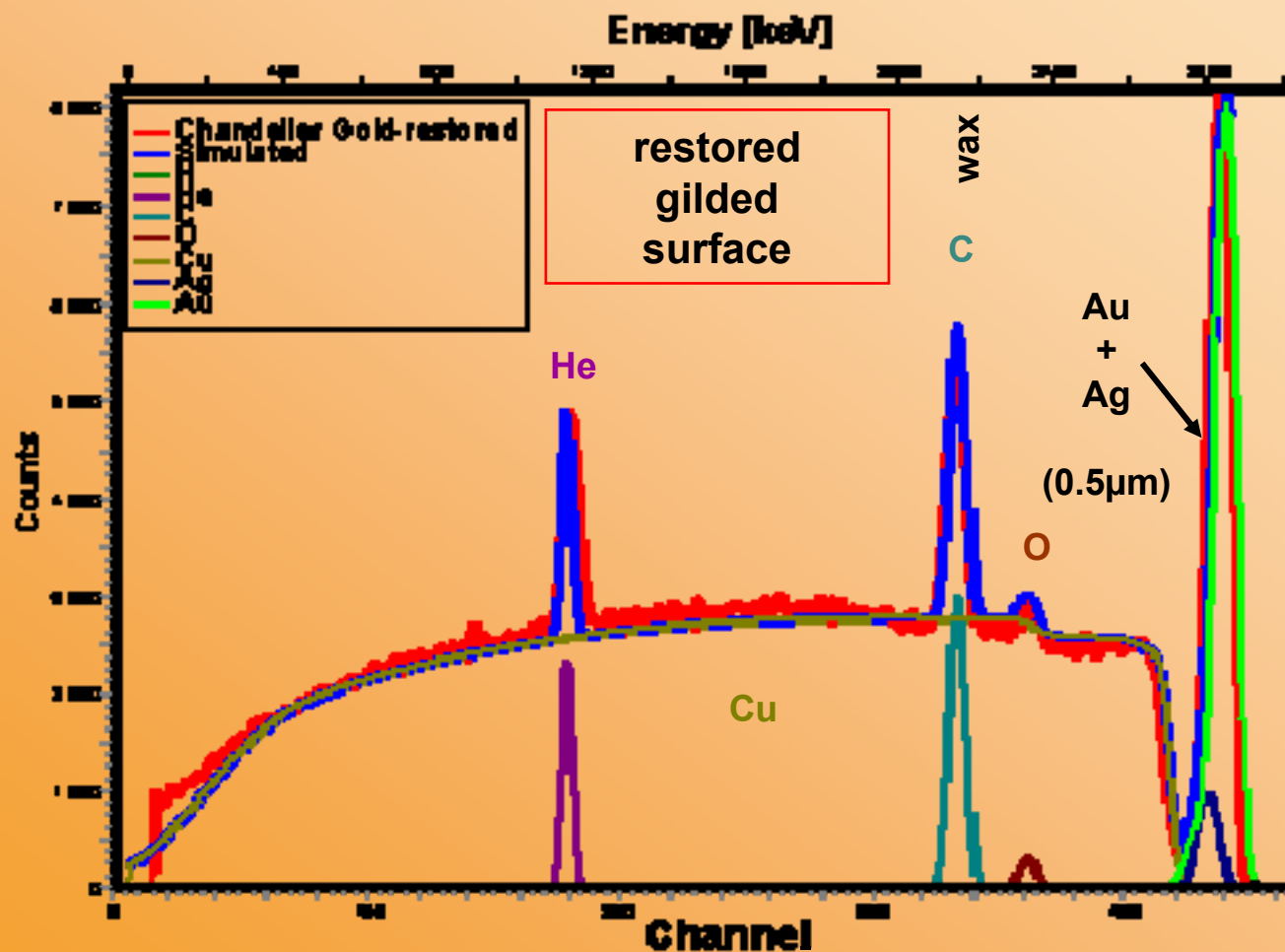


A 6 metre diameter “crown of light” figuring the celestial Jerusalem

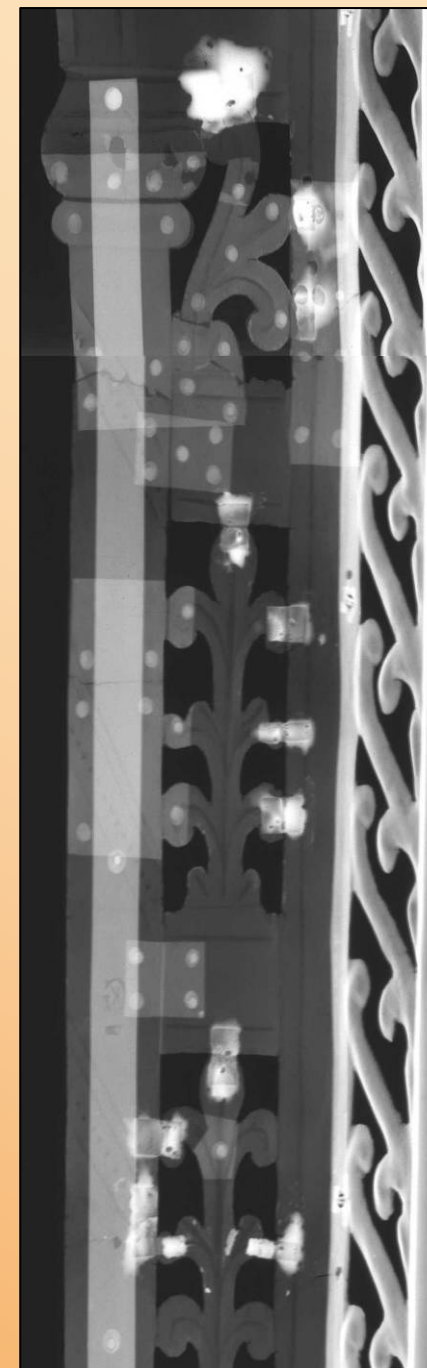
- 1055 : manufactured during the episcopate of bishop Hezilo
- 1901 : deep restoration (pieces replacement, gilding)
- 1948 : soft restoration (cleaning, wax layer applied)
- 2001 : parts of the chandelier in Paris for an exhibition



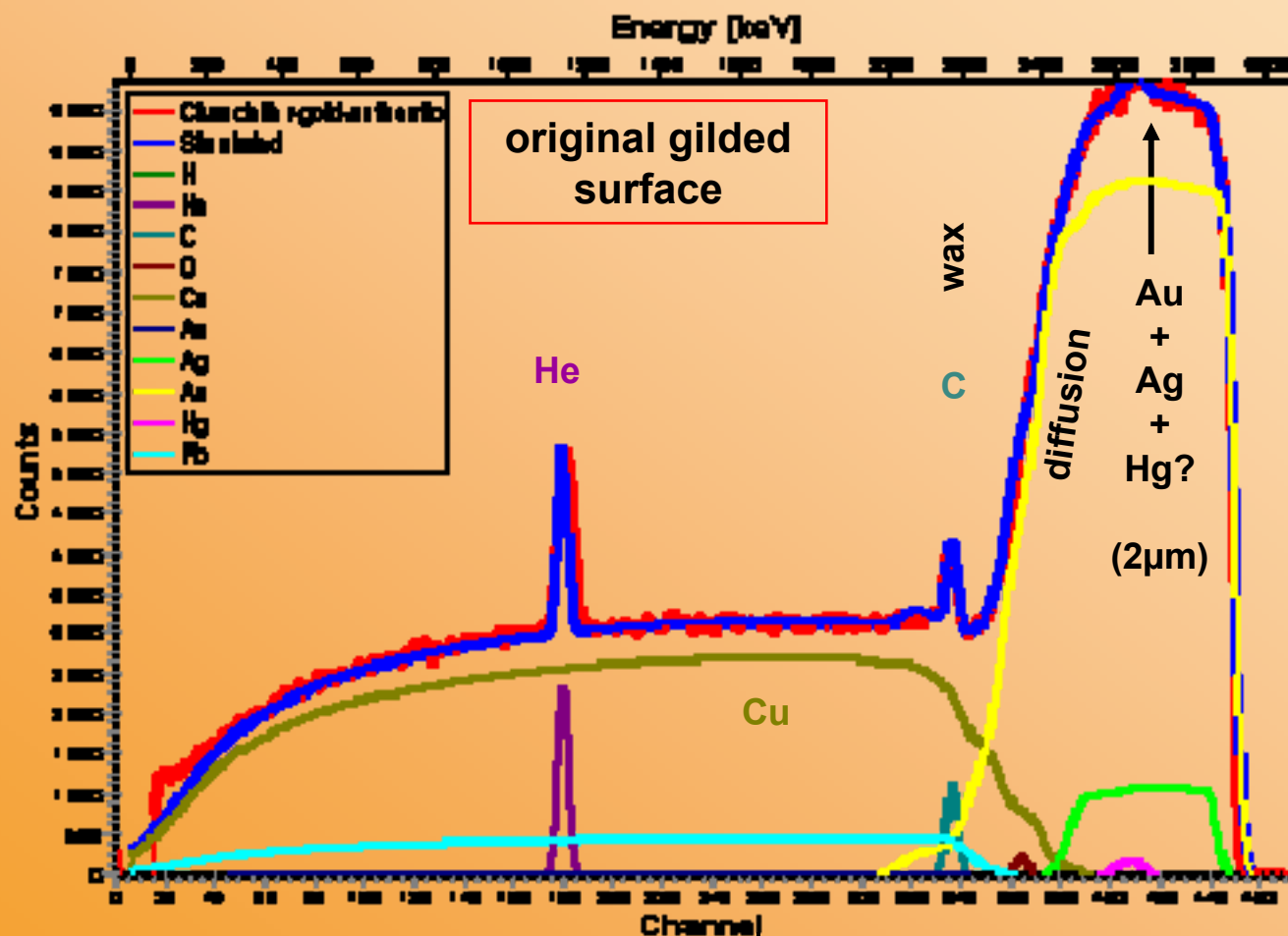
Hildesheim Dom Cathedral “The Hezilo Leuchter“



A 3 MeV proton RBS spectrum, showing the thickness of the gold layer, confirmed these PIXE observations (very thin gold layer for electrolytic gilding...).



Hildesheim Dom Cathedral “The Hezilo Leuchter“



A 3 MeV proton RBS spectrum, showing the thickness of the gold layer, confirmed these PIXE observations (thick gold layer for amalgam gilding...).



Analysis of the Sky Disk of Nebra with Synchrotron Radiation X-Ray Fluorescence (Sy-XRF)

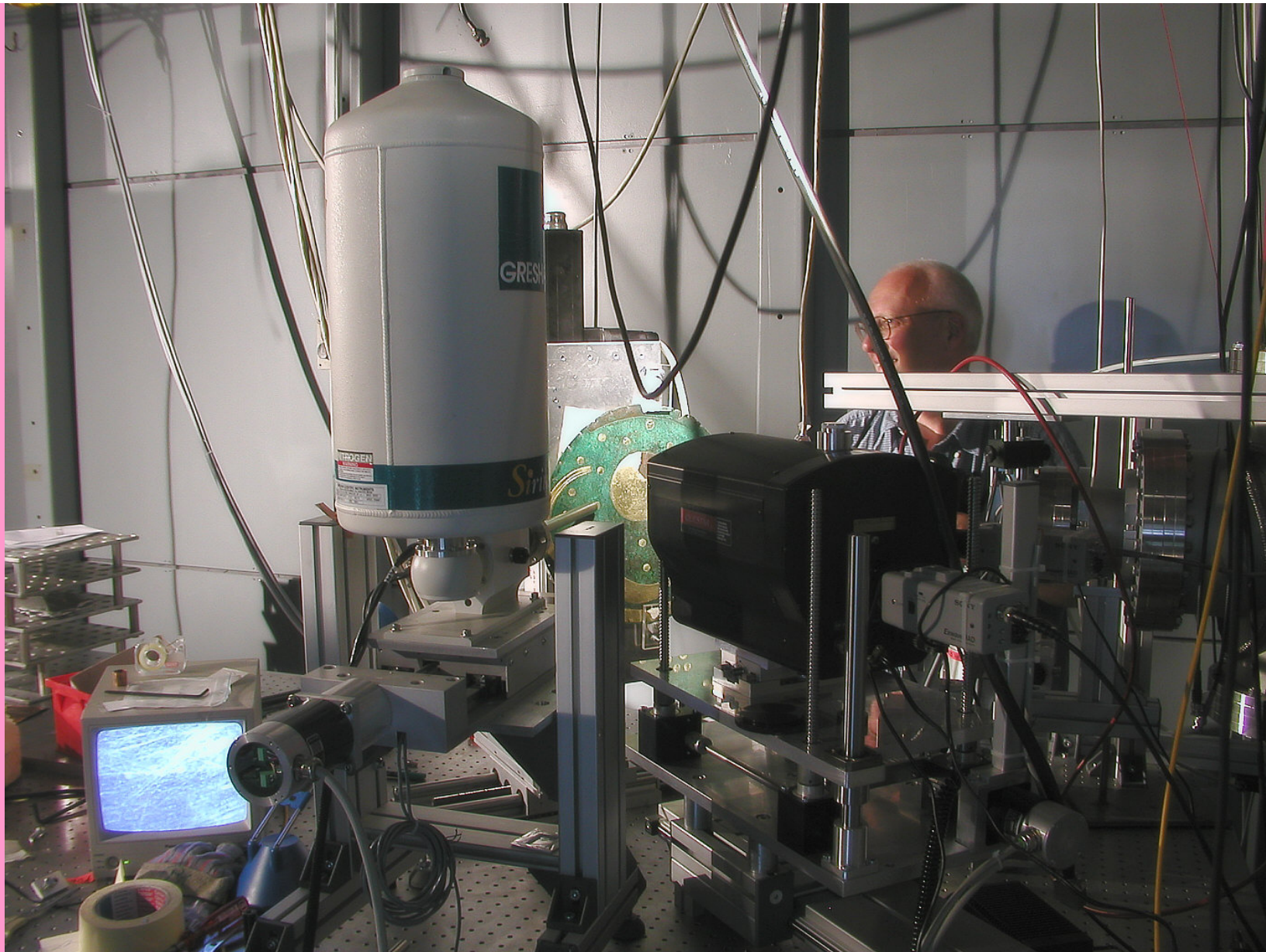
time range ~3600 years ago

E. Pernicka et al., BESSY Highlights 2003

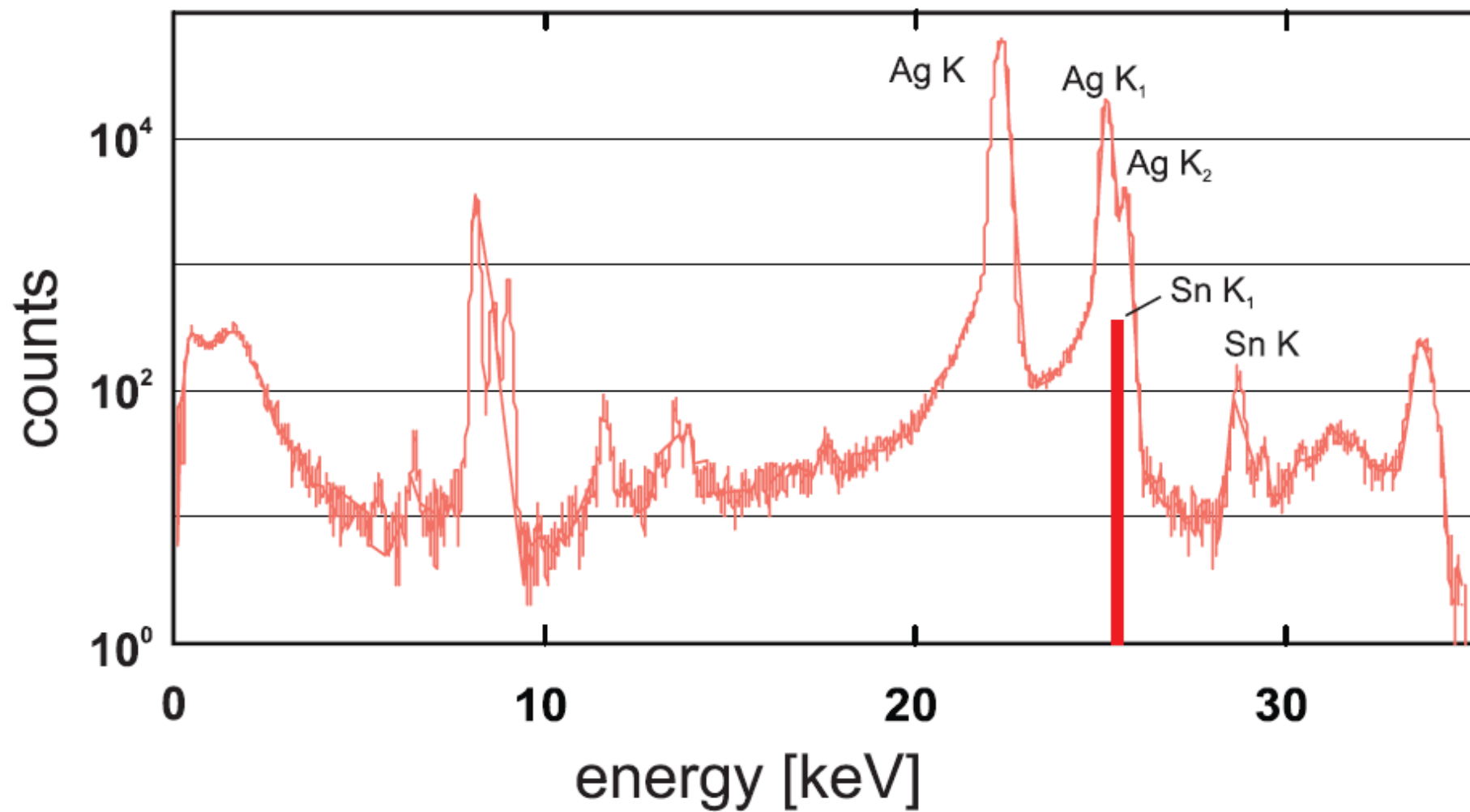


The Sky Disk from Nebra near Halle, Germany (dia = ~32 cm)

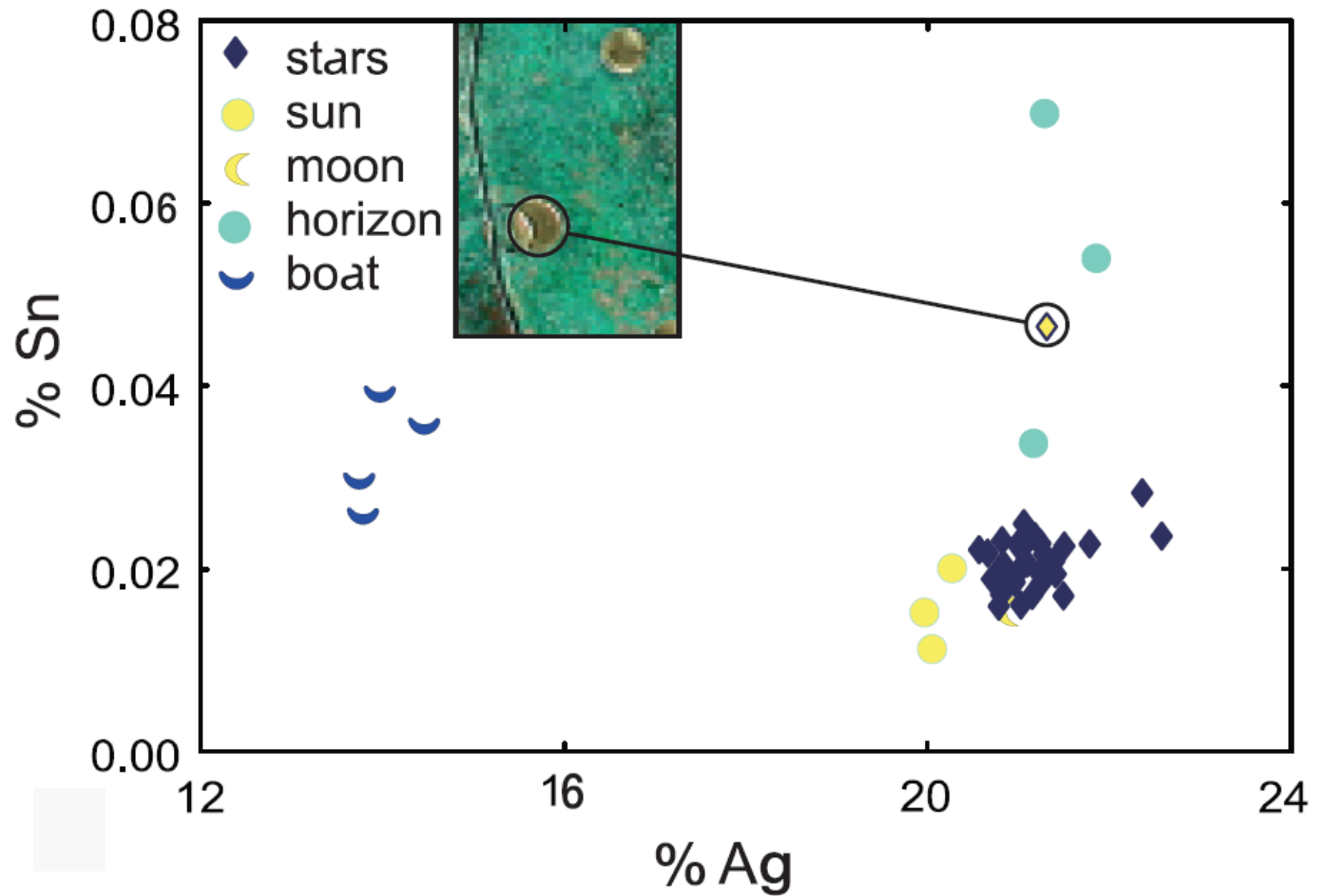
In addition, Bronze Age artifacts were found: two swords with gold decorated hilts, two flanged axes, a chisel and two arm spirals



**Experimental Set-up at the BAMline of the
Synchrotron Source BESSY in Berlin**



Energy region of the Sn K _{α} X-ray spectrum of gold on the Sky disk



Sn and Ag concentrations in the gold parts of the Sky disk

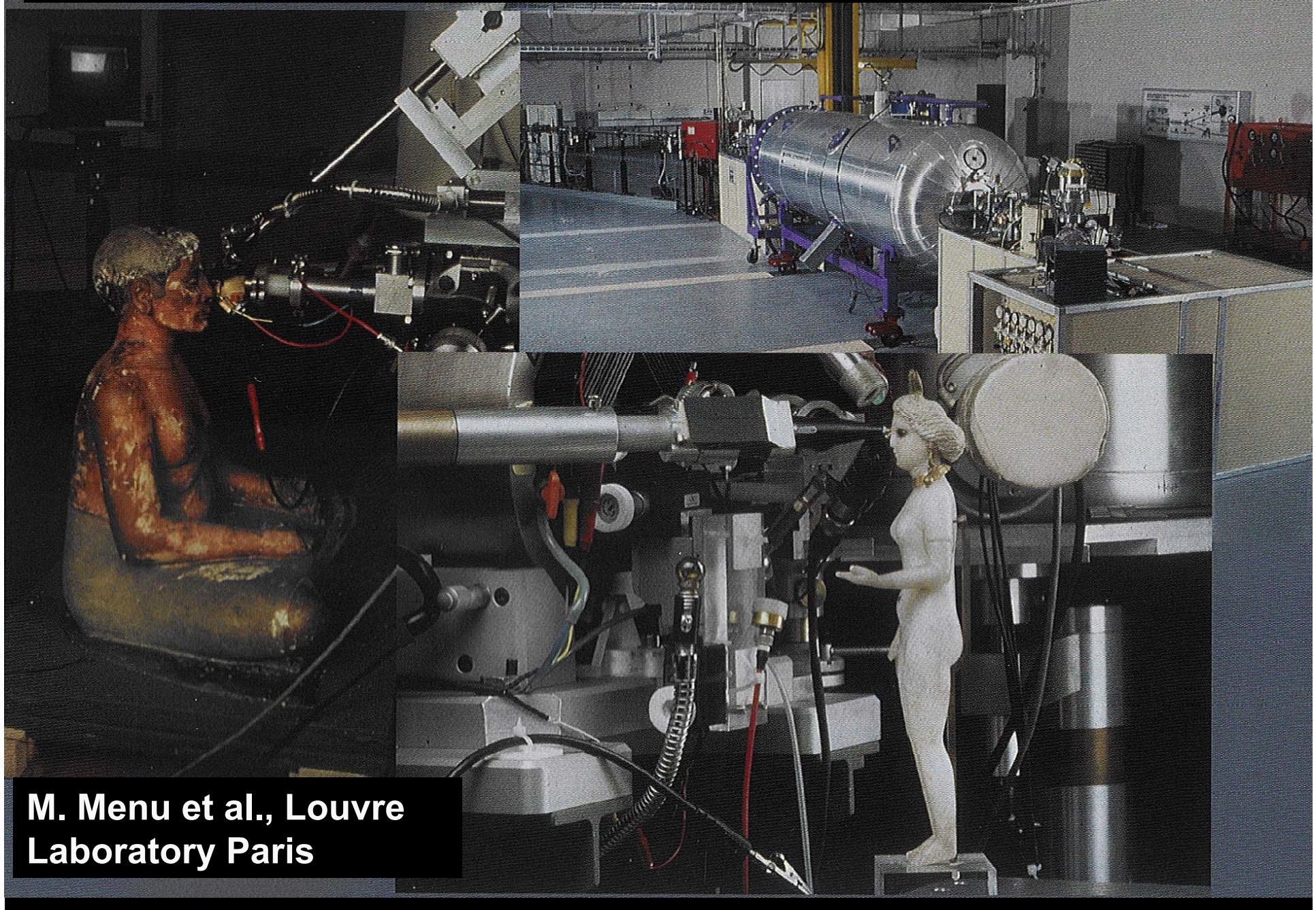
European Network of Competence at 1600 BC

“With the gold from the Carpathian basin, the copper from Austria, and the ‘technology transfer’ from Mycenae (Greece) the manufacturing of the Nebra Sky disk can be considered as a very early endeavour based on joint European experience, possibly spiced with symbolism from Egypt or the Levant“

--- Ernst Pernicka



Cover of *Nuclear Physics News International* 16/4 (2006)



**M. Menu et al., Louvre
Laboratory Paris**